Marine and Estuarine Ecosystem and Habitat Classification

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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Marine and Estuarine Ecosystem and Habitat Classification

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Preface

The Ecological Society of America and NOAA's Offices of Habitat Conservation and Protected Resources sponsored a workshop to develop a national marine and estuarine ecosystem classification system. Among the 22 people involved were scientists who had developed various regional classification systems and managers from NOAA and other federal agencies who might ultimately use this system for conservation and management. The objectives were to: (1) review existing global and regional classification systems; (2) develop the framework of a national classification system; and (3) propose a plan to expand the framework into a comprehensive classification system.

Although there has been progress in the development of marine classifications in recent years, these have been either regionally focused (e.g., Pacific islands) or restricted to specific habitats (e.g., wetlands; deep seafloor). Participants in the workshop looked for commonalties across existing classification systems and tried to link these using broad scale factors important to ecosystem structure and function.

A consensus developed during the workshop that a classification system would provide a useful common language for description of habitat and a framework for interpretation of ecological function. However, all agreed that a system currently did not exist that was both broad enough in scope and fine enough in detail to be useful at the national level. Participants developed a classification framework that blended global scale systems with regional systems to provide a prototype classification system. The prototype system was hierarchical and used a combination of physical and biological information to classify "ecological units" (eco-units) which serve as a representation of the biological community or assemblage within a given habitat.

Introduction

Why do we need a marine and estuarine ecosystem classification system?

Marine species and their habitats are increasingly impacted by development, pollution, fishing and other human activities. Concern over loss of biological diversity and ecosystem function has caused us to realize that the traditional species-by-species approach to conservation and management can no longer stand alone, and must be supplemented by efforts that consider whole ecosystems and their natural communities. This has led to the implementation of an "ecosystem approach" to conservation that generally includes ecosystem classification and inventory and landscape ecology. Although the ecosystem approach has been widely used in terrestrial systems, there has been less effort in marine and estuarine ecosystems.

Efforts to inventory and classify ecosystems and to construct habitat maps require a classification system with common terminology. Such efforts require that people who construct habitat maps, resource managers, and scientists have a common "language". A marine and estuarine ecosystem classification system will enable natural resource managers to effectively and expeditiously identify threatened or representative biological communities, and gaps in their coverage (i.e., lack in conservation efforts to ensure protection), so these ecosystems can be protected and conserved. The research community at large will also derive significant benefits from a consistent classification framework within which to synthesize information on the ecological characteristics of marine and estuarine ecosystems.

The classification system should satisfy several basic needs:

1. Provide a consistent system covering all states, territories, commonwealths, and other sovereign possessions of the United States – this will allow us to: (a) prepare an inclusive inventory, or census, of ecosystems at the local, regional, and national levels; (b) track changes in these ecosystems over time; and (c) ensure additivity that will allow classification to proceed to the finest level accommodated by available data and still fit into an overall system.

2. Focus on the distinguishable natural community and its physical environment – this would include both abiotic (e.g., geophysical or geomorphological features) and biotic (e.g., live organisms structuring bottom cover) characteristics. An ultimate goal of the classification system is to provide a tool for conservation, and therefore it must include the biotic component.

3. Allow us to identify and map eco-types (coarse-level description of biological community associated with physical variables) – this map of eco-types would serve as a primary GIS "base layer" on top of which could be placed overlays of fishery and protected species distributions and the quality, condition and health of the ecosystem based on its biological attributes.

4. Accommodate limited data and available technology – information may initially have to be aggregated at a general level of the hierarchy, particularly for deeper water and pelagic ecosystems; mapping will be limited to what technology allows us to see or interpret. For example, we cannot identify coral species from airborne remote sensing. In the absence of species data from the field, a more generic term such as coral is the best we can do.

5. Provide the basis for developing functional links between underlying mechanisms structuring the ecosystem and the described biological community.

In doing so, this classification system should provide:

- A framework for interpretation of ecological function
- A consistent terminology, including a glossary of terms

Relationship to Other Classification Efforts

This effort looked for commonalities in regional schemes and tried to link these with broad-scale forcing functions. Allee (in review) prepared a synthesis that compared and contrasted similarities and differences of existing classification systems. Cowardin et al. (1979) produced the only national classification effort to include major marine habitats. However, the scale of their system did not provide a useful basis for conservation decisions. Other systems have concentrated on broad biogeographic approaches (e.g., Hayden and Ray 1984) and there has been progress in the development of marine ecosystem classification in recent years at regional scales (e.g., Pacific islands, Holthus and Maragos 1995, State of Washington, Dethier 1992), or restricted to specific lifeforms (e.g., wetlands, Cowardin et al. 1979). However, of the systems reviewed, none were inclusive of all marine habitats found in U.S. waters. Our effort not only provides a classification approach for all marine and estuarine ecosystem types, but is designed to interface with existing terrestrial (e.g., national vegetation classification system, FGDC 1997) and freshwater systems (The Nature Conservancy 1996).

The Proposed U.S. Marine and Estuarine Ecosystem Classification System

Overview

Our goal was to develop a classification system that describes the spatial heterogeneity of marine and estuarine landscapes and is logically linked to underlying mechanisms structuring the ecosystem and biotic communities. This system should be broadly applicable and consistent, with categories that are mutually exclusive and additive (i.e., accommodating to additions resulting from new technology and information on ecosystems). This system should incorporate primary environmental variables and have modifiers that allow a general description to become incrementally more specific, so that eventually these variables describe the abiotic portion of a biotic community. This system represents a combination of expert knowledge and a consensus-based approach at the higher levels, and an empirical data-based approach at the lower levels.

The draft classification system is a blend of theoretical and pragmatic, and physical and biotic structuring variables. At the lowest level (eco-unit) of the system, we incorporate biotic features, highlighting the dependence of ecosystems on biological processes and interactions. An eco-unit is the smallest element of the ecosystem as a whole and it represents the biological community or assemblage that is the product of the physical and biotic variables above it. For example, a mudflat with seagrass is a very different ecosystem for organisms than a mudflat without. More importantly, however, the eco-unit is the closest approximation to the biotic community, the ultimate conservation target. The classification system is structured to allow aggregation at different levels depending on the amount of data available on an ecosystem.

Aggregating at higher levels results in more general information. However, as more specific information becomes available, more specific categorization can occur. This was necessary because the amount of information available on many ecosystems is limited. To accommodate this practical need, the position in the hierarchy of some of the variables is some what arbitrary

and is based on the probability of the information being available. For example, although sediment type is an important structuring variable in the benthos, it is often not known until late in the identification process. We often know that a site is an "intertidal flat" before we know if it is a mud or sand flat. Thus we have a general eco-type, intertidal flat, which can be further classified as a mud or sand flat as this information becomes available.

The resulting classification system consists of 13 levels (Table 1, Figures 1 and 2). Each level of the hierarchy is discussed below beginning at the highest (geographically most broad) or most general level.

Life zone - Level 1

At the top of the hierarchy, we have included "life zones". These are large spatial scale, regional divisions based largely on climate, such as temperate or polar zones. We chose not to include more specific "biotic provinces" because these change with the taxa considered. Life zones are widely recognized and remain constant worldwide, although there are many marine taxa that are not restricted by these zones.

Water/Land - Levels 2 and 3

The next hierarchical level provides for a division of terrestrial (land) and water components of the earth. This is followed by a division of the water component (Level 3) into marine/estuarine and freshwater. These two divisions are necessary to enable this classification system to be linked into classification systems for terrestrial and freshwater realms. The system presented here only follows the water - marine/estuarine path. Marine habitats only occur in the "water" component.

Continental/Non-continental (Oceanic) - Level 4

The hierarchical categorization of continental versus non-continental waters is important because of the influence that land masses can have on marine systems. For example, freshwater runoff from continental landmasses can cause large variations in the salinity of estuarine waters or serve as a source of pollutants. The freshwater runoff volumes from non-continental landmasses are generally less significant in influencing the surrounding waters accept at a local scale. Another example is that most of the nation's coral reefs lack connection or association with the continental United States. Continental is defined in reference to ecosystems or other classification features attached to or contiguous to the continental United States, including Alaska and islands of the continental shelf.

Bottom/Water Column - Level 5

The next division separates the bottom, and those organisms (benthic) associated with it, from the water column lying above. Benthic organisms are influenced by the various characteristics of the bottom (e.g., substrate particle size, topography, etc.) as well as by characteristics of the

water column such as currents and tides; those organisms residing within the water column will primarily be influenced by the latter. These two systems are thus very different, although not totally independent, particularly where overlying waters are shallow or very close to the bottom.

Shelf, Slope, and Abyssal - Level 6

The next hierarchical level addresses depth at a large scale. Depth is a natural part of any marine classification and represents a major ecological division. We adopted three subdivisions of depth: shallow (on or over the continental shelf, < 200 m); mid-depth (on or over the continental slope, 200 - 1000 m); and deep (on or over the rise and deeper features, > 1000 m).

Regional Wave/Wind Energy - Level 7

Regional energy is addressed at a large scale compared to local energy which is considered later in the system as a modifier. This category is important because the amount of wind or wave action that an ecosystem is exposed to can significantly impact the stability of that system and thus influence the organisms. We selected two subdivisions for this category: exposed/open, which encompasses those areas that are open to full oceanic wave or wind energies; and protected/bounded (partially or fully) which encompasses those areas that are protected from full wave or wind energies by nearshore islands or shallow bathymetry, or by partial or full enclosure in bays or lagoons.

Hydrogeomorphic (Hydroform) or Earthform Features - Level 8

Hydrogeomorphic and earthform features are addressed within the system on a broad scale. An earthform is a geomorphological feature of the earth's crust while a hydroform is a hydromorphological feature of the earth's water. These features are included because they are indirect indicators of a variety of physical forcing functions and are broad indicators of structure in the marine environment. For example, high and low relief earthforms support different communities of fish species. Hydroforms were identified because they are an important constraint on marine communities. For example, high current areas are typically highly productive because the currents increase the availability of nutrients to sessile organisms and these areas are almost always well-mixed. There can be numerous subdivisions of these categories. Examples of continental categories include: nearshore (surf zone); inshore (rest of shelf); straight or partially enclosed shorelines; lagoons; fjords; embayments; estuaries; outer shelf; upper slope; and submarine canyon. Non-continental categories include: island; atoll; and submerged reef types (refer to Holthus and Maragos 1995).

Hydrodynamic Features - Level 9

Smaller hydrodynamic features allow the system to begin focusing on regional or local habitat types. This category has four subdivisions: supratidal (above high tides); intertidal (extreme high to extreme low water); subtidal (below extreme low water); and circulation features (e.g., eddies). The first three subdivisions generally apply to benthic habitats, while the circulation features apply to water column habitats.

Photic/Aphotic - Level 10

Photic/aphotic separation is based on the compensation depth for photosynthesis; above this depth is photic and below is aphotic. These categories apply to both benthic and water column habitats.

Geomorphic Types or Topography - Level 11

This category has many subdivisions which apply to much smaller scales and more localized areas than the higher hierarchical level of broad hydrogeomorphological features. Some of the possible subdivisions include: on shorelines –> cliff, bench, flat, etc.; on reefs –> reef flat, spur-and-groove, sand bar, etc.

Substratum and Eco-type - Level 12

Substratum is an important constraint on benthic and demersal communities and can also be an indicator of the local environmental energy regime and substrate stability. This category follows the standard Wentworth scale for particle or sediment size class divisions (e.g., cobble, pebble, sand, silt) and includes classes for bedrock, boulder, biogenic, organic, and anthropogenic. Eco-type is a coarse-level description of the biological community (e.g., as visible in aerial surveys) associated with the combination of physical variables (including substratum type) in the hierarchy above it. Eco-types may be named for a dominant, readily-visible biotic element such as seagrass, mangroves, coral reefs, or kelp bed. In the absence of a readily-visible biotic element, this level of the system may be named for the substratum and slope, such as a mud (substratum) flat (slope). Because the eco-type and substratum components are so intrinsically related, we place them parallel in the hierarchical structure. Often, eco-type will be easier to determine than substratum because, by definition, eco-type is immediately visible, whereas substratum classification may require field sampling and analyses.

Local Modifiers and Eco-units - Level 13

The eco-types need to be refined further by local modifiers to describe a particular location or characteristic type, designated the eco-unit. Ultimately, the local modifiers will be prioritized and defined in such a way to capture functional as well as structural aspects of a specific habitat type. Local modifiers may also constitute parameters to monitor over time and space for detecting change or degradation. Local modifiers are used to further define an eco-type in lieu of adding more levels. This keeps the classification simple and allows aggregation at a general level. Possible modifiers include: temperature, local energy regime (waves, tides, current), salinity, nutrients, alkalinity, roughness/relief, dynamism, edge effects from adjacent areas, anthropogenic disturbances, biological interactions, history of extreme events. Preferably, each local modifier used is quantitatively. Table 2 provides a preliminary list of eco-types from the workshop, with some lists of local modifiers added.

While local modifiers appear at the end of our hierarchical structure, modifiers in general are not necessarily restricted to use for modification of eco-types. A review of existing classification systems (Table 3) found that modifiers were used at various levels within the hierarchical

structure (Allee, in review). Cowardin et al. (1979) uses modifiers on the class or subclass categories to help fully describe the habitats. The Cowardin system includes a water regime modifier, a water chemistry modifier, which for the marine and estuarine components only includes salinity, and "special" modifiers, designed to focus on anthropogenic changes of the habitat such as excavation and drainage. Dethier (1992), Brown (1993), Wieland (1993), and Holthus and Maragos (1995) also use a salinity modifier. Holthus and Maragos (1995) use substratum as a modifier at the lowest level of their hierarchy. Dethier (1992), Wieland (1993), Holthus and Maragos (1995), and Greene et al. (1999) include waves/currents as an "energy" modifier. Brown (1993) developed the only system that identifies temperature as a modifier.

Ecological units (eco-units) are the elements at the lowest level of this classification although they are considered parallel to local modifiers at level 13. They represent the biological community or assemblage that is the "product" of all the higher hierarchical categories plus modifiers. They are a practical construct to allow categorization of sites at the level appropriate to the application and describe the individual biotic community. Eco-units may provide the most useful level of detail for most applications, particularly when the goal is conservation or understanding of biological diversity or ecosystem patterns or processes. Eco-unit in this proposed system is distinguished by the combination of environmental factors and its dominant or characteristic benthic or water column species, both plant and animal. If no one species is dominant, then the habitat is simply described by its detailed physical variables. This is consistent with the use of "ecological unit" by Holthus and Maragos (1995), but differs from the term "eco-unit" used by Zacharias et al. (1998) which referred only to physical characteristics of an area. This also differs from the common approach in terrestrial classification systems that tend to use a combination of geology and vegetation, but not animals, to define ecological units. In many marine systems, animals can be as important as plants in structuring habitats and are sometimes the most conspicuous life forms (e.g., coral or oyster reefs). In addition, animals are often the focus of conservation or exploitation and their distribution and abundance is not always easily predicted on the basis of plant species (Conroy et al. 1996). We recommend that classification activities try to reach the eco-unit level when possible.

Application of the Classification System

Workshop participants sought to apply this classification framework to selected ecosystems. We classified six different systems in our initial efforts to assess this hierarchy: continental salt marsh (Figure 3), continental water column (Figure 4), continental shoreline (Figure 5), deep benthic (Figure 6), mangrove (Figure 7), and coral reefs (Figure 8). Within each application, the higher levels of the hierarchy (levels 1 through 5) were easily classified. Regional energy was easily classified for all five ecosystems as were the categories for broad hydrogeomorphic or earthform features and smaller hydrodynamic features. No classification was given for the lower hierarchical level of photic/aphotic for the continental water column application because the organisms are not influenced by the compensation depth when they have the ability to move freely in and out of these two zones. The system becomes more complex when we try application at the lower levels, beginning with geomorphic types or topography (level 11), since there is so much diversity at this level.

For shoreline systems, we were able to apply information at each hierarchical level, in part because much information is available for these ecosystems. The system also works well for benthic continental outer shelf and upper slope ecosystems, mangroves, and salt marshes. The system works well, in part, because of the parallel structure at levels 12 and 13. For ecosystems that are poorly known for substratum type, for instance, classification can still occur at the visible biotic level, e.g., kelp bed, which is the eco-type. We can classify at the eco-type level without knowing the substratum and we can classify by local modifiers (e.g., salinity) without necessarily knowing the community composition. Within the continental water column habitat type, geomorphic types and topography are really not applicable.

Continental Water Column Habitat

The example used for this habitat is northeastern temperate Pacific, water, and marine (Figure 4). It is continental (Level 4) because distinguishing features of the water masses derive from the interaction of the prevailing winds and currents with the continental land mass.

The example habitat is defined as water column rather than benthic, and neritic (nearshore) rather than pelagic (Level 5). Level 6 describes the underlying bathymetric zone, which is the continental shelf (<200 m depth). Level 7 defines the relative exposure to ocean processes. While parts of the example habitat are somewhat protected, as a whole it is dependent on its exposure to ocean processes (wind and wave energies). At Level 8, it is over the continental shelf but beyond the surf zone, therefore characterized as inshore.

Level 9 describes the smaller hydrodynamic features; water column habitats are generally defined by circulation features and the topography of the seafloor. The defining characteristics of these habitats are determined more by processes than by structure; for example, current gyres, seasonal ice formation, storm events. In the example habitat, the prevailing winds from the northwest result in several areas of recurrent upwelling of cold nutrient-rich water in certain seasons. As upwelled water ages, plankton proliferates in the water mass and eventually become a critical food source for higher trophic organisms downstream.

Modifiers for upwelling areas include the following: (1) Local jets and eddies which themselves are ephemeral but recurrent features determine the distribution of the upwelled water as it ages. Typically, areas with older upwelled water are richer in biota than those with fresh upwelled water. Not all areas receive old upwelled water, and this is reflected in corresponding variation in the local communities. (2) Proximity of nesting habitat/hauling grounds – high densities of some species, notably seabirds and pinnipeds, tend to be associated with nearness to islands or certain coastal habitats. (3) Substratum—while substratum is not explicitly part of the water column, it may influence the distribution of some water column species that feed on the bottom, such as Gray whales, or animals whose adult phase is benthic but whose juvenile phase inhabits water column habitats such as rock fish. (4) Tidal plumes—river or estuarine outflow may also affect species distribution, particularly within the range of the outflow plume.

The habitat includes both the photic and aphotic zones (Level 10), as organisms move freely between them. Level 11 (geomorphic types) does not apply to water column habitats. Substratum (Level 12) does not apply directly to water column habitats, although substratum can be important as a modifier (see Level 9).

The Temperate Pacific Upwelling Community (Gulf of the Farallones) is characterized by a species assemblage that feeds on plankton blooms that develop in the nutrient rich upwelled water, notably humpback whales and Cassin's Auklets. The zooplankton community is dominated by two species of euphausids, *Ehysanoessa spinifera* and *Euphausia pacifica.* Seabirds, especially auklets and murres, nest on the Farallon Islands, a rocky archipelago located along the edge of the shelf. Sooty Shearwaters are migrants that are seasonally present in large numbers. The fish community is dominated by anchovy, sardine, and juvenile rockfish, especially the short-bellied rockfish. These rockfish are benthic in their adult phase, but pelagic during their juvenile phase.

Continental Shoreline Habitat

The upper layers of the hierarchy for the continental shoreline habitat example are: temperate eastern Pacific, water, marine. Shorelines are found on both continental and non-continental areas, with unexplored differences between them. All shorelines then fall under benthic, shelf categories. Our example (Figure 5) proceeds to an open/exposed shoreline, i.e. one that experiences oceanic swell and large wind-waves, whereas protected/bounded shorelines are in bays, behind islands, or bordered by extensive shallow bathymetry that absorbs the energy of ocean waves. Level 8 has a variety of categories listed in Table 1; shorelines will always fall within nearshore (those affected by surf, usually <10m depth) for the exposed/open category. Modifiers at this level, constraining lower categories, could include mean annual water temperature, and mean annual salinity.

At the lower levels of the hierarchy, shorelines then fall clearly under intertidal (and supratidal, when this is of interest), and are entirely in the photic zone. Level 11 (shore type) describes the overall geomorphology, on a >100m linear scale, such as cliff, bench, tide flat, spit, etc. Modifiers at this level could include finer geomorphic descriptors, such as whether the cliff is eroding or contains caves, or whether a lagoon is open or closed off from the sea.

Level 12 specifically defines substratum form and materials, which are critical in determining shoreline biota, and are definable on a smaller scale (10-100m). On shorelines, categories here can range from anthropogenic structural wood to clastic sand to volcanic bedrock. Modifiers at this level could include: length, width, and area of the shoreline, substratum grain size, wave energy, aspect, sediment source, sediment abundance, and sediment transport direction. This combination of variables, including local modifiers, can be used to define an eco-type, or a general type of biotic community visible at the 10-100m scale, often visible in aerial surveys. For the exposed rocky shoreline example (Figure 5), in the northeast Pacific on boulder and bedrock substrata, zoned or banded biota such as barnacle, mussel, and kelp beds can define an eco-type.

Level 13 then can include further modifiers of the shoreline type, such as tidal elevation, substratum size distribution, wave energy dissipation, wave runup, roughness, permeability, seepage, slope, and dynamism. These modifiers result in a better-defined biotic community, described from field samples. In our rocky shore example, if modifiers include low tidal elevation, moderate energy dissipation and low wave runup, and moderate dynamism, the community could be categorized as one including specific kelps and invertebrates as shown in Figure 5.

Mangrove Ecosystems

The life zones used for mangrove ecosystems, tropical and subtropical, are basically the Latitudinal Regions of Holdridge's (1974) life zones; the humidity provinces are included in the local modifiers below. Since marine systems do not have altitudinal belts - but do have depth as in level 6 - only the latitudinal effects are necessary here. This distinction between tropical and subtropical is very important for the functional characteristics of mangroves - and possibly the demographic features as well. There is a clear pattern of mangrove biomass and productivity with latitude; *Avicennia* is more cold tolerant than *Rhizophora* which changes the species composition along the coast in tropical versus subtropical climates.

Level 4 represents continuity, or lack thereof, with the continental United States. Mangroves fall into both continental and non-continental categories. This is the first major division in the categories.

Level 7 defines the degree of exposure an eco-type is subjected to. There are a few examples of exposed mangroves on shorelines but most are protected as indicated by the types of geomorphological features chosen for the classification system (Figure 6). Thus only protected is used.

Several features are identified at level 8, "Broad Hydro-Geomorphic Features". The continental group (deltas, estuaries, lagoons, and carbonate settings) is largely based on a combination of systems developed by Thom (1982) and Galloway (1982). According to Woodroffe (1992), there would be six groups under continental but Rias and Tide-dominated settings have been included under estuaries, and the Delta-Lagoon Complex was not included. The non-continental grouping (volcanic island, low island, reefs, atolls) follows the Pacific system.

At level 11, "Geomorphic Types or Topography", three categories were identified: riverine, fringe, and inland. This classification follows a modification of the Lugo and Snedaker (1974) scheme and follows the triangle of Woodroffe (1992) of mangrove systems. Categories 1, 8, and 11 constitute the classification system for mangroves proposed by Twilley (1997), and make up the major categories of the system for mangroves.

There are four basic types of sediment (Level 12, "Substratum") that are associated with mangroves (Chapman 1976, Hutchings and Saenger 1987): peat, sand, silt/mud, and carbonate. This is a major multiplier effect on the number of eco-units in the system. Carbonate was excluded in many combinations of geomorphic and topographic features. For example, there are

no carbonate substrata among the topographic features under deltas, and silt/mud is not found under fringe and inland features of carbonate settings. This helps to reduce the number of eco-units.

Four local modifiers were used in the draft classification for mangroves (Figure 6). They include more specific information on biogeographic province, storm class, salinity regimes, and humidity province; each of these has specific references that can be used to classify the appropriate region or class. Biogeographic province includes New World Tropics and Old World Tropics (Tomlinson 1986). This is an important determinant of demographic features of the eco-unit. There is tremendous difference in mangrove tree diversity in these two regions but there is no evidence that there is a functional difference in mangroves associated with this tree diversity. Storm (disturbance) classes are categorized as low or high (Lugo 1978). This is important in determining the demographic and functional features of mangroves associated with the 'maturity' of the site. The frequency of hurricanes in the Caribbean region is a good example. Salinity regime of tidal waters is categorized by hypersaline (>35 ppt), marine (30-35 ppt), and brackish (0.2-30 ppt). Models of mangrove hydrology show that the salinity of flood waters together with humidity province are important determinants of soil salinity (Twilley and Chen 1998). This will influence the demographic and functional features of, particularly, the inland mangrove types. The humidity province (Holdridge 1974) may be categorized as humid (PET:P ratio <1.0), semiarid/subhumid (PET:P ratio 1.00-4.00), or arid (PET:P ratio >4.00). This is an important determinant of demographic and functional characteristics of inland mangroves; and also indicates the susceptibility of mangroves to freshwater input from rivers (Blasco 1984).

Benthic Continental Outer Shelf and Upper Slope

The life zone for the benthic continental outer shelf and upper slope example is temperate northeast Pacific. This example is based on the zoogeographic regions and provinces described by McGowan (1971) and Allen and Smith (1988). This life zone comprises the Oregonian Province within the Boreal (cold-temperate) Eastern Pacific Region of the temperate North Pacific. It is bounded by Cape Flattery, WA to the north and Point Conception, CA (perhaps discontinuously to include upwelling zones off northern Baja CA) to the south. This example also follows Hedgpeth's (1957) and Allen and Smith's (1988) marine life zone classification schemes, which divide the marine environment by depth and proximity to the seafloor (either pelagic or benthic). According to these two studies, our benthic example would encompass the Outer Sublittoral Shelf Zone (100-200 m) and the Mesobenthal Zone (200-500 m).

The categories for level 8 ("Broad Hydrogeomorphic Features and Earthforms") correspond to Greene et al.'s (1999) "Subsystem" based on physiography and depth (Figure 8). There are three categories: outer continental shelf, upper continental slope, and upper submarine canyon. This nomenclature is based on the classification structure developed by Greene et al. (1999).

At level 11, "Geomorphic Types or Topography", 7 categories exist: crevice, slump, rockfall, terrace, ledge, overhang, and steeply sloping. These designations follow the Greene et al. (1999) classification scheme, corresponding to their 'Class' based on seafloor morphology (e.g., crevice, slump, rockfall, etc.) and to their 'Subclass' based on slope (steeply sloping = 30-45°).

Following the "subclass" category of Greene et al. (1999), that was based on substratum size and texture, there are four dominant benthic macro- and micro-habitats described for level 12. These are: mud, boulder, bedrock, and organic debris.

Several local modifiers were identified for this eco-type. The following non-exhaustive examples modify seafloor morphology, deposition, and texture and also biological and anthropogenic processes, after Greene et al. (1999). For seafloor morphology: Outcrop Bedding and Relief/Roughness. For seafloor deposition: Consolidation (un-, semi-, well-consolidated), Erodability (uniform, differential), and Sediment cover thickness (dusting <1 cm; thin = 1-5 cm; thick >5 cm). For seafloor texture: Voids (percentage volume occupied by clast or rock), Clast (rock) shape, Particle concentration (e.g., boulder density), Occasional Scattered (features cover 10-50% of area), Contiguous (features are close-to-touching), and Pavement (features continuous). For biological processes: Bioturbation (amount of excavation; burrows; tracks; etc.), Cover of encrusting organisms (continuous; patchy; little), and Communities of conspicuous species. For anthropogenic processes: Dredge spoils, Trawl and dredge tracks and furrows, Discarded and lost fishing gear, Artificial reefs, Oil and gas rigs.

Bocaccio, Cowcod, Greenspotted, and Rosethorn Rockfish, Lingcod, Sea Anemone, and Crinoids are dominant species of an eco-unit associated with the Deep Rock Outcrop eco-type off central California (see Yoklavich et al. In Press). The dominant fish and macroinvertebrate species that comprise the resultant eco-unit (or assemblage) have extensive geographic ranges; their distribution and abundance will depend on several physical factors (e.g., light, temperature, pressure, which all co-vary with depth at specific latitudes) and on the impacts of fishing (many of these species are both recreationally and commercially valuable).

Comparison to the EUNIS System

The European Environment Agency has been developing "a common parameter-based European habitat classification frame ..." (European Environment Agency 1999). The agency's habitat classification "forms an integral part of the European Topic Centre on Nature Conservation (ETC/NC) nature information system (EUNIS) (European Environment Agency 1999). This system differs from the marine and estuarine system proposed here in that the EUNIS habitat classification is designed to address *all* habitat – terrestrial, freshwater, and marine. The marine component to this system was derived from the BioMar project (Connor et al. 1997).

While EUNIS is certainly broader than what we have attempted here, much of the rationale for developing such a consistent habitat classification system is the same. The aims and requirements of the EUNIS system include, but are not limited to:

- providing a common and easily understood language for description;
- being objective and scientifically based;
- being comprehensive, but applicable at a number of hierarchical levels of complexity; and
- being flexible so as to evolve and allow the admission of new information.

Each of these corresponds to objectives identified at the workshop.

The EUNIS approach also shares many of the foreseeable uses of such a system, namely:

- to obtain an overview of habitat distribution;
- to evaluate habitat diversity; and
- to identify threatened habitat types.

The upper levels of the EUNIS habitat classification system are shown in Figure 9. Tables 4 - 7 show the proposed U.S. marine and estuarine habitat classification for salt marsh, water column, shoreline, and mangrove habitats, respectively, with a corresponding classification using the EUNIS system. Here, the EUNIS system begins at the equivalency of the proposed system's level 3a, marine. There is no category for continental versus non-continental in the EUNIS system, a factor of the regional development. The proposed U.S. system considers depth (level 6) and exposure (level 7) as distinct categories whereas the EUNIS system combines these two to create a matrix of categories at the 1st level after marine. These categories include: littoral rock and other hard substrata; littoral sediments; sublittoral rock and other hard substrata; sublittoral sediments; bathyal zone; and abyssal zone. The proposed system's level 9, "hydrodynamic features", is also considered within this matrix. The EUNIS system has no equivalent hierarchical structure for levels 10 (photic/aphotic), 12b (eco-type), or 13a and 13b (local modifiers and eco-unit) of the proposed system.

Conclusion

Development of a consistent, hierarchical ecosystem and habitat classification system will provide a powerful tool for resource managers. This system meets the general needs of resource managers that result from limited data while also meeting specific needs necessary for conservation of ecosystem biodiversity. We have already begun verification of the system for various habitat types and these efforts have proven useful in identifying areas within this proposed system that will require further refinement. We intend to continue this verification process following release of this system as necessary to gain buy-in from the research community, resource managers, and decision makers.

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Table 1. Proposed Marine and Estuarine Ecosystem Classification System.

1. Life Zone –
    1a. Temperate
    1b. Tropical
    1c. Polar

2. Water/Land
    2a. Terrestrial
    2b. Water

3. Marine/Freshwater
    3a. Marine/Estuarine
    3b. Freshwater

4. Continental/Non-Continental
    4a. Continental
    4b. Non-Continental

5. Bottom/Water Column
    5a. Bottom (Benthic)
    5b. Water Column

6. Shelf, Slope, Abyssal
    6a. Shallow – on or over the continental shelf; <200m
    6b. Medium – on or over the continental slope; 200 - 1000m
    6c. Deep – on or over the rise and deeper features; >1000m

7. Regional Wave/Wind Energy
    7a. Exposed/Open – open to full oceanic wave or wind energies
    7b. Protected/Bounded – protected from full wave or wind energies

8. Hydrogeomorphic or Earthform Features
    8a. Continental - Nearshore (surfzone); Inshore (rest of shelf); Straight or partially enclosed shorelines; Lagoons; Fjords; Embayments; Estuaries - Shore zone; Off shore zone; Delta; Carbonate settings; Outer continental shelf; Upper continental slope; Upper submarine canyon
    8b. Non-Continental - Island (Volcanic; Low); Atoll; Submerged reef types

9. Hydrodynamic Features
    9a. Supratidal – above high tides
    9b. Intertidal – extreme high to extreme low water
    9c. Subtidal – below extreme low water

Table 1 (Continued). Proposed Marine and Estuarine Ecosystem Classification System.

9. Hydrodynamic Features (Continued)
    9d. Circulation features – e.g., eddies

10. Photic/Aphotic
    10a. Photic
    10b. Aphotic

11. Geomorphic Types or Topography - Cliff; Bench; Flat; Reef flat; Spur-and-Groove; Sand bar; Crevice; Slump; Rockfall; Terrace; Ledge; Overhang; Steeply sloping; Riverine; Fringe; Inland; Beach face; Dunes

12. Substratum and Eco-type
    12a. Substratum (Not limited to this list) - Cobble; Pebble; Sand; Silt; Mud; Bedrock; Peat; Carbonate; Boulder; Biogenic; Organic; Anthropogenic
    12b. Eco-type (Not limited to this list) - Coastal; Soft bottom; Hard bottom; Water column; Beach; Mangrove; Wetland; Seagrass bed; Coral reef; Kelp bed; Mud flat

13. Local Modifiers and Eco-unit
    13a. Modifiers (Not limited to this list) - Temperature; Local energy regimes – waves, tides, current; Salinity; Nutrients; Alkalinity; Roughness/relief; Dynamism; Edge effects – from adjacent areas; Anthropogenic disturbances; Biological interactions; Extreme events – history
    13b. Eco-units - Unlimited representation of species resulting from modifiers applied at the above hierarchical levels.

Table 2. Preliminary list of eco-types as identified during the Marine and Estuarine Habitat Classification Workshop, October, 1999. Latitude and major climate characteristics are defined higher in the hierarchy.

ECO-TYPES Coarse level description of biological community - often as visible from aerial photographs. This list can be expanded or re-worked as regional experts discuss eco-types for a particular region.	**LOCAL MODIFIERS USED FOR ECO-TYPES** A non-exhaustive list of quantitative and qualitative modifiers. The most important modifiers for each eco-type should be listed and ranked. Examination of all the possible combination of modifiers should provide a quantitative description of individual eco-units.	**EXAMPLES OF ECO-UNITS** Eco-units are the "product" of the entire hierarchy - a biological community or assemblage of species that can be defined by choices throughout all 13 levels, and then further defined by a set of local modifiers. Eco-units can refer to a specific location or many locations depending on the specific habitat. This process can be a mechanism of "grouping" or "splitting" habitat units. Eco-units are "user-defined" and are repeating units of species which can occur on a variety of scales.
1. Coastal eco-types with some component that is inter-tidal.		
Salt Marshes This eco-type can occur on a scale of 1 to 10's of kilometers. The size of the marsh community is dependent on the key modifiers	Components that can be present: creeks, emergent vegetation, mud flats. **Key Modifiers:** 1) Sediment source and composition 2) Local Temperature/Climate 3) Salinity regimes 4) Marsh vegetation/water interface 5) Tidal energy (range, frequency) 6) Nutrients sources and characteristics 7) Coastal geomorphology and elevation 8) Coastal hydrology and exposure	Salt marshes can be described as fringing, riverine, brackish or upland transition marshes. Salt marshes can also be named by the dominant vegetation species. The names and descriptions of salt marshes will vary with region
Mangrove Wetlands	Mangrove wetlands are defined globally by latitude, climate and biogeography.	
Mud Flats		
Beaches		
Cobble or Boulder Shores		
Coastal Cliffs		
Rocky Shores	Information on exposure type is included in upper levels of hierarchy - local modifiers include: 1. Dominant species or suites of conspicuous species 2. Minor geographical differences	
2. Soft bottom or unconsolidated bottom eco-types.		
Subtidal Sandy Bottom	**Key Modifiers:** 1. Depth 2. Bioturbation 3. Relief, sediment grain size and shell hash 4. Water movement and boundary currents 5. Geology	Examples include: Amphioxus Sands Mega Ripple sand communities

Table 2 (Continued). Preliminary list of eco-types as identified during the Marine and Estuarine Habitat Classification Workshop, October, 1999. Latitude and major climate characteristics are defined higher in the hierarchy.

Seagrass Beds	**Key Modifiers:** 1. Sediment type and depth 2. Water depth 3. Species of seagrasses present 4. Density of seagrass (biomass, stem count)	
Algal Beds		
Mud Bottom		
Oyster Reefs		
3. Hard bottom or consolidated bottom eco-types.		
True Coral Reefs (biogenic substrate actively accreting carbonate)	**Key Modifiers:** 1. Reef morphology- patch, bank barrier, fringing, etc. 2. Depth zone 3. Energy and nutrient zone 4. Dominant species 5. Whether contiguous to land	Florida Keys Patch Reefs Pacific Fringing Reefs Pacific Barrier Reefs Pacific Lagoon (patch & pinnacle) reefs Pacific Atolls Pacific Submerged Reefs (e.g., no association with emergent land)
Low Relief Hard Bottom, or Offshore Live Bottom (not a useful name based on the wide scope of modifiers and types discussed from different regions - this name includes kelp forests to soft coral/sponge reefs)	**Key Modifiers:** 1. Water Depth 2. Geological origins - sediment source or starvation, passive margins? 3. Light levels on the substrate 4. Dominant species or co-dominance of benthos; shifting or steady state mosaics 5. Outcroppings, topography 6. Currents and energy regime 7. Nutrient regimes 8. Igneous rock or consolidated sediments	
Worm Reefs		
4.) Water column eco-types. These can occur on a much larger scale than many benthic habitats, stretching into the 1000's of kilometers.		
Coastal Shelf	Key Modifiers: 1. Water column depth 2. Surface temperature regimes 3. Dynamic animal assemblages 4. Water masses and scale 5. Current systems, gyre and eddie dynamics 6. Upwelling and nutrient regimes	Southern California Bight

Table 3. A comparison of modifiers used in existing classification systems reviewed by Allee (in review) and those proposed for the National Marine and Estuarine Habitat Classification System. MC indicates the system was developed out of a modification to the Cowardin system.

Source	Type of Habitat	Types of Modifiers Used	Region
Proposed National Marine and Estuarine Habitat Classification	Marine and estuarine	Non-exhaustive: examples include: temperature, local energy regime (waves, tidal, current), salinity, nutrients, alkalinity, roughness/relief, dynamism, edge effects from adjacent areas, anthropogenic disturbances, biological interactions, history of extreme events	United States
Brown 1993 (MC)	Benthic	Depth, salinity, mud, organic, bioherm, temperature	Maine
Cowardin et al. 1979	Deep water and wetlands	Water regime, salinity, pH, soil, special (excavated, impounded, diked, partly drained, farmed, artificial)	United States
Dethier 1992 (MC)	Marine and estuarine	Energy, tidal, depth, salinity	Washington state
Greene et al. 1999 (MC)	Benthic	Bottom morphology, bottom deposition, bottom texture, physical processes, chemical processes, biological processes, anthropogenic processes	Pacific coast of United States
Holthus and Maragos 1995	Ocean/ benthic	Light level, geology, sediment type, salinity, steepness/slope gradient, exposure, reef top width, % reef perimeter, orientation, substrate, surface, lagoon size, lagoon area, No. of patch reefs/pinnacles, high island, atoll perimeter length, reef islet type	Tropical Island Pacific
Wieland 1993 (MC)	Marine and estuarine	Depth, salinity	Mississippi

Table 4. Classification of a salt marsh habitat using the proposed classification system with a comparison to the EUNIS Habitat Classification.

Proposed U.S. Marine and Estuarine Habitat Classification System:

1. Life Zone
   1a. Temperate
2. Water/Land
   2b. Water
3. Marine/Freshwater
   3a. Marine/Estuarine
4. Continental/Non-Continental
   4a. Continental
5. Bottom/Water Column
   5a. Bottom (Benthic)
6. Shelf, Slope, Abyssal
   6a. Shallow
7. Regional Wave/Wind Energy
   7b. Protected/Bounded
8. Hydrogeomorphic or Earthform Feature
   8a. Estuary - Shore zone
9. Hydrodynamic Features
   9b. Intertidal
10. Photic/Aphotic
    10a. Photic
11. Geomorphic Types or Topography
    Beach face
12. Substrate and Eco-type
    12a. Organic
    12b. Salt marsh
13. Local Modifiers and Eco-unit
    13a. Salinity - Brackish
    13b. *Phragmites*

European Environment Agency, EUNIS Habitat Classification for marine habitats (to level 3):

A. Marine
A2. Littoral sediments
    With angiosperms (see note a6)
    Dominant angiosperm is terrestrial (see note a7)
A2.6 Coastal salt marsh and saline reed beds
    Frequently submerged (see note a9)
    Continuous vegetation (see note a10)
A2.64 Low-mid salt marshes

Notes:

a6 - Habitats dominated by aquatic (e.g. *Zostera* spp.) or terrestrial (e.g. *Salicornia* spp.) Angiosperms, are distinguised from those dominated by animal communities, with or without algae.

a7 - Angiosperm-dominated habitats are differentiated between those whose dominant species are entirely aquatic but which can tolerate occasional emersion (e.g. *Zostera* spp., *Ruppia* spp., *Posidonia* sp.), and those which are primarily terrestrial but can tolerate varying amounts of immersion (e.g. *Salicornia* spp., *Spartina* spp.).

a9 - Saltmarsh habitats are separted according to the water regime (determined by the position on the shore), between those frequently submerged, with soil moisture and salinity relatively constant, and infrequently submerged, with soil moisture and salinity variable.

a10 - Habitats with pioneer vegetation dominated by annualk or perennial species with <30% vegetation cover are separated from those with more-or-less continuous

Table 5. Classification of a water column habitat using the proposed U.S. Marine and Estuarine Habitat Classification system with a comparison to the EUNIS Habitat Classification.

Proposed U.S. Marine and Estuarine Habitat Classification System:

1. Life Zone
   1a. Temperate
2. Water/Land
   2b. Water
3. Marine/Freshwater
   3a. Marine/Estuarine
4. Continental/Non-Continental
   4a. Continental
5. Bottom/Water Column
   5b. Water column
6. Shelf, Slope, Abyssal/Water Column
   6b. Water column
7. Regional Wave/Wind Energy
   7a. Open
8. Hydrogeomorphic or Earthform Features
   8a. Inshore (rest of shelf)
9. Hydrodynamic Features
   9d. Circulation features - Upwelling area
10. Photic/Aphotic
    Both 10a. Photic and 10b. Aphotic
11. Geomorphic Types or Topograpy
    Not applicable
12. Substrate and Eco-type
    12a. **Substrate not applicable**
    12b. Water column plankton community
13. Local Modifiers and Eco-unit
    13b. Birds: Sooty Shearwater (*Puffinus griseus*), Cassin's Auklet (*Ptychoramphus aleuticus*), Rhinoceros Auklet (*Cerorhinca monocerata*), Common Murre (*Uria aalge*), Mammals:Dall's Porpoise (*Phocoenoides dalli*), Humpback Whale (*Megaptera novaengliae*), Fish: Anchovy, Sardines, Juvenile Rockfish, Invertebrates: *Ehysanoessa spinifera, Euphausia pacifica*

European Environment Agency, EUNIS Habitat Classification for marine habitats (to level 3):

A. Marine
A7. Pelagic Water Column (see note a40)
A7.A Open ocean habitats with currents and eddies

Notes:

a40 - Large oceanic fronts (zones at the interface between two masses of water of different properties) and transient open ocean patterns are distinguised.

Table 6. Classification of a continental shoreline habitat using the proposed classification system with a comparison to the EUNIS Habitat Classification.

Proposed U.S. Marine and Estuarine Habitat Classification System:

1. Life Zone
    1a. Temperate Eastern Pacific
2. Water/Land
    2b. Water
3. Marine/Freshwater
    3a. Marine/Estuarine
4. Continental/Non-Continental
    4a. Continental
5. Bottom/Water Column
    5a. Bottom (Benthic)
6. Shelf, Slope, Abyssal
    6a. Shallow
7. Regional Wave/Wind Energy
    7a. Exposed/Open
8. Hydrogeomorphic or Earthform Feature
    8a1. Nearshore
        Modifiers: Mean annual water temperature, mean annual salinity
9. Hydrodynamic Features
    9b. Intertidal
10. Photic/Aphotic
    10a. Photic
11. Geomorphic Types or Topography
    Rock platform
        Modifier: very exposed
12. Substrate and Eco-type
    12a. Boulder
        Modifier: irregular low tide platform
    12b. Kelp bed
13. Local Modifiers and Eco-unit
    Local Modifiers
        Roughness/relief
        Dynamism
        Elevation
        Substrate size distribution
        Wave energy dissipation
        Wave runup
        Permeability
        Seepage
        Slope
    13b. Eco-unit - species list

European Environment Agency, EUNIS Habitat Classification for marine habitats (to level 3):

A. Marine
A1. Littoral rock and other hard substrata
    Moderately exposed (see note a4)
A1.2 Littoral rock moderately exposed to wave action

Notes:

a4 - The criterion separates out habitats which are very exposed to wave and/or tidal action from those only moderately exposed or sheltered.

Table 7. Classification of a mangrove habitat using the proposed classification system with a comparison to the EUNIS Habitat Classification.

Proposed U.S. Marine and Estuarine Habitat Classification System:

1. Life Zone
    1a. Tropical
2. Water/Land
    2b. Water
3. Marine/Freshwater
    3a. Marine/Estuarine
4. Continental/Non-Continental
    4a. Continental
5. Bottom/Water Column
    5a. Bottom (Benthic)
6. Shelf, Slope, Abyssal
    6a. Shallow
7. Regional Wave/Wind Energy
    7b. Protected/Bounded
8. Hydrogeomorphic or Earthform Feature
    8a. Lagoon
9. Hydrodynamic Features
    9b. Intertidal
10. Photic/Aphotic
    10a. Photic
11. Geomorphic Types or Topography
    Riverine
12. Substrate and Eco-type
    12a. Sustrate
        Peat
    12b. Eco-type
        Mangrove
13. Local Modifiers and Eco-unit
    13a. Modifiers
        Salinity
    13b. Eco-unit - species

European Environment Agency, EUNIS Habitat Classification for marine habitats (to level 3):

A. Marine
A2. Littoral sediments
    With angiosperms (see note a6)
    Dominant angiosperms are aquatic (see note a7)
A2.7 Littoral sediments dominated by aquatic angiosperms

Notes:

a6 - Habitats dominated by aquatic (e.g. *Zostera* spp.) or terrestrial (e.g. *Salicornia* spp.) Angiosperms, are distinguised from those dominated by animal communities, with or without algae.

a7 - Angiosperm-dominated habitats are differentiated between those whose dominant species are entirely aquatic but which can tolerate occasional emersion (e.g. *Zostera* spp., *Ruppia* spp., *Posidonia* sp.), and those which are primarily terrestrial but can tolerate varying amounts of immersion (e.g. *Salicornia* spp., *Spartina* spp.).

Table 8. Marine and Estuarine Habitat Classification Glossary

Aphotic – The layer of a body of water where there is not enough light for photosynthesis to occur

Benthic - the portion of the marine realm that is on, in or close to the ocean floor regardless of depth

Boundary current – the part of the fast flowing, oceanic current that is concentrated near the eastern edge of an ocean, relatively close to the western shore

Continental – water and benthos that borders land masses, occupying the zone extending seaward from the low-tide line to a depth where the continental shelf meets the abyss or any attribute that is derived from interaction with the continental landmass

Demersal - associated with the bottom but not of the substrate

Estuary – a distinctive body of water in which fresh water flowing from the land mingles with the salt water of the ocean, where the salinity is between that of the ocean and fresh water, and contains a distinct population of animals and plants. Not inclusive of fjords and lagoons

Fjord – narrow, deep, steep-walled inlet of sea formed either by submergence of mountainous coast or by entrance of sea into deeply excavated glacial trough after melting away of the glacier

Geomorphology types – Description of the composition and relevant topography of the substrate (i.e., coral, biogenic sand)

Habitat - an identifiable and distinct association of physical characteristics and associated biological assemblage used by an organism or community

Hydrographic features – characteristics of the water such as: temperature, salinity, chemical composition, and currents

Inshore – from the shoreline to the seaward edge of the breaker zone

Intertidal – the zone from extreme high water to extreme low water

Lagoon - shallow water between a bar, barrier reef, mainland, or an atoll

Nearshore - area between the surf zone and the edge of the continental shelf

Non-boundary current - the part of the fast flowing, oceanic current that is to the southern, northern, or western part of the ocean

Non-continental – water and benthos beyond the edge of the continental shelf, including those

surrounding *non-* continental islands

Pelagic - in the water column and not associated with the benthos

Photic - the layer of a body of water that enough light penetrates for photosynthesis to occur.

Rise - on the continental fringe; > 1000 m depth; long, broad elevation that rises gently and generally smoothly from the sea floor

Shelf - < 200 m depth, submerged boarder of landmasses that occupies the zone extending seaward from the low-tide line to a point where the ocean bottom abruptly slopes more steeply toward greater depth

Slope - 200 - 1000 m depth; section of the benthos that is seaward of the continental shelf and drops steeply to the abyss

Substrate types – grain size according to the Wentworth scale

Subtidal – below the level of extreme low tide

Supratidal – the zone just above the extreme high water to the point where most terrestrial life stops

Surf zone (near shore) - the part of the inshore zone where wave turbulence extends to the bottom

Temperature/latitude - Holdridge 1974

Topographic features - relief features on large spatial scale

Figure 1. Levels 1 through 8 of the proposed National marine and estuarine habitat classification system. Dashed boxes indicate a continuation of the classification system that is not shown on this diagram. Refer to Table 1 for a more comprehensive list.

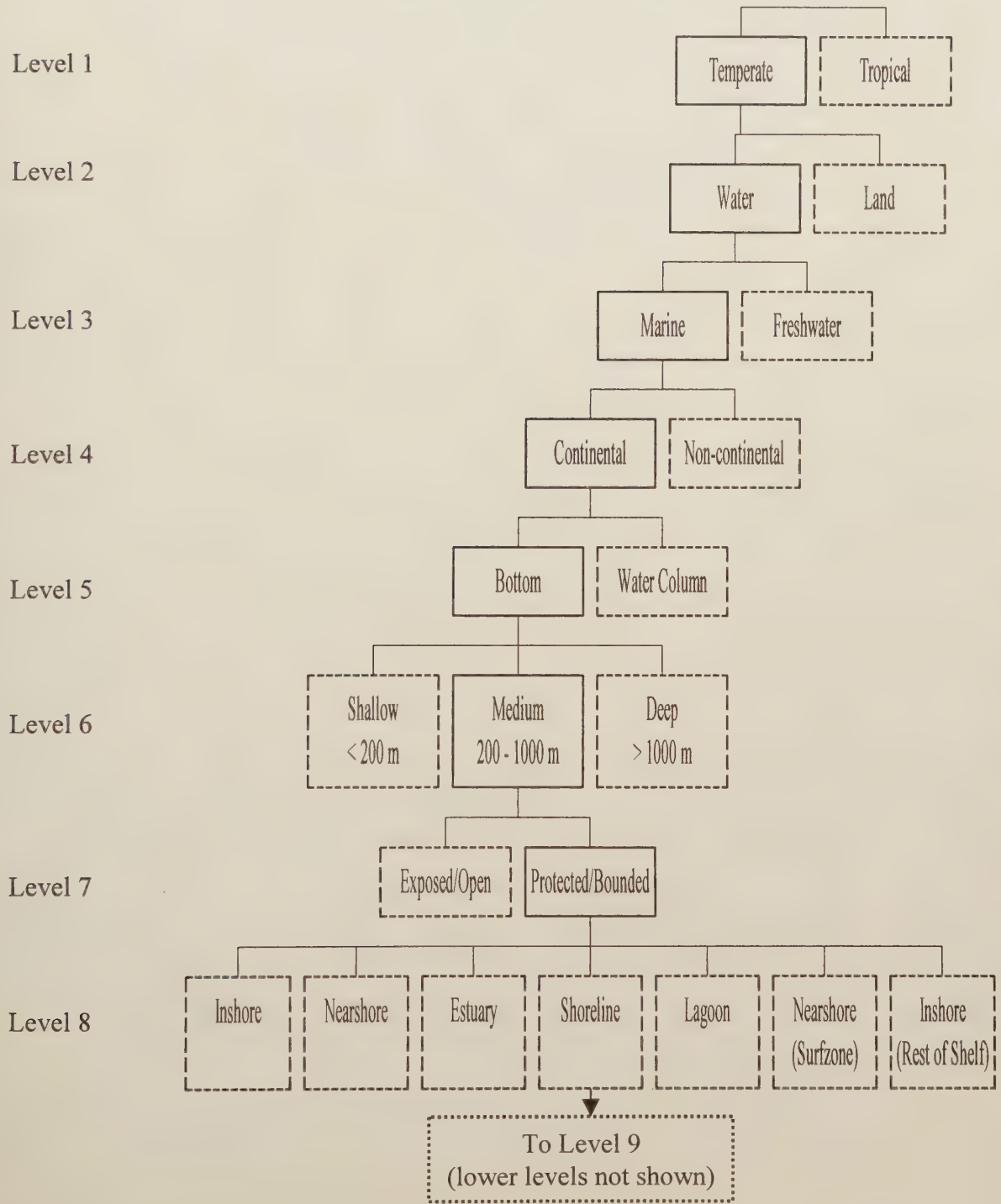


Figure 2. Levels 9 through 13 of the proposed National marine and estuarine habitat classification system. Dashed boxes indicate a continuation of the classification system that is not shown on this diagram. Not all options for each level are shown on this diagram. Refer to Table 1 for a more comprehensive list.

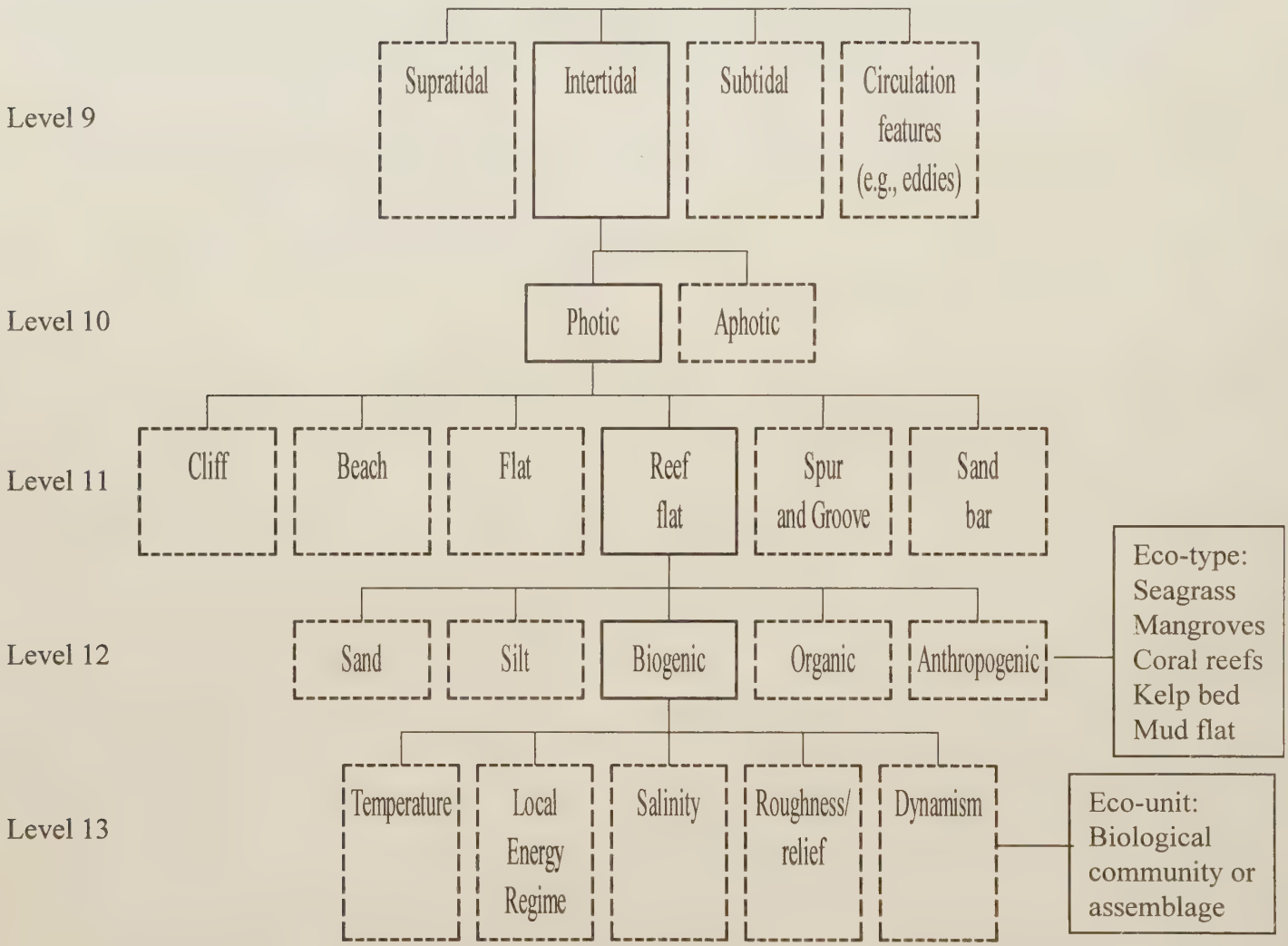


Figure 3. Levels 8 through 13 of the proposed marine and estuarine habitat classification system for a salt marsh.

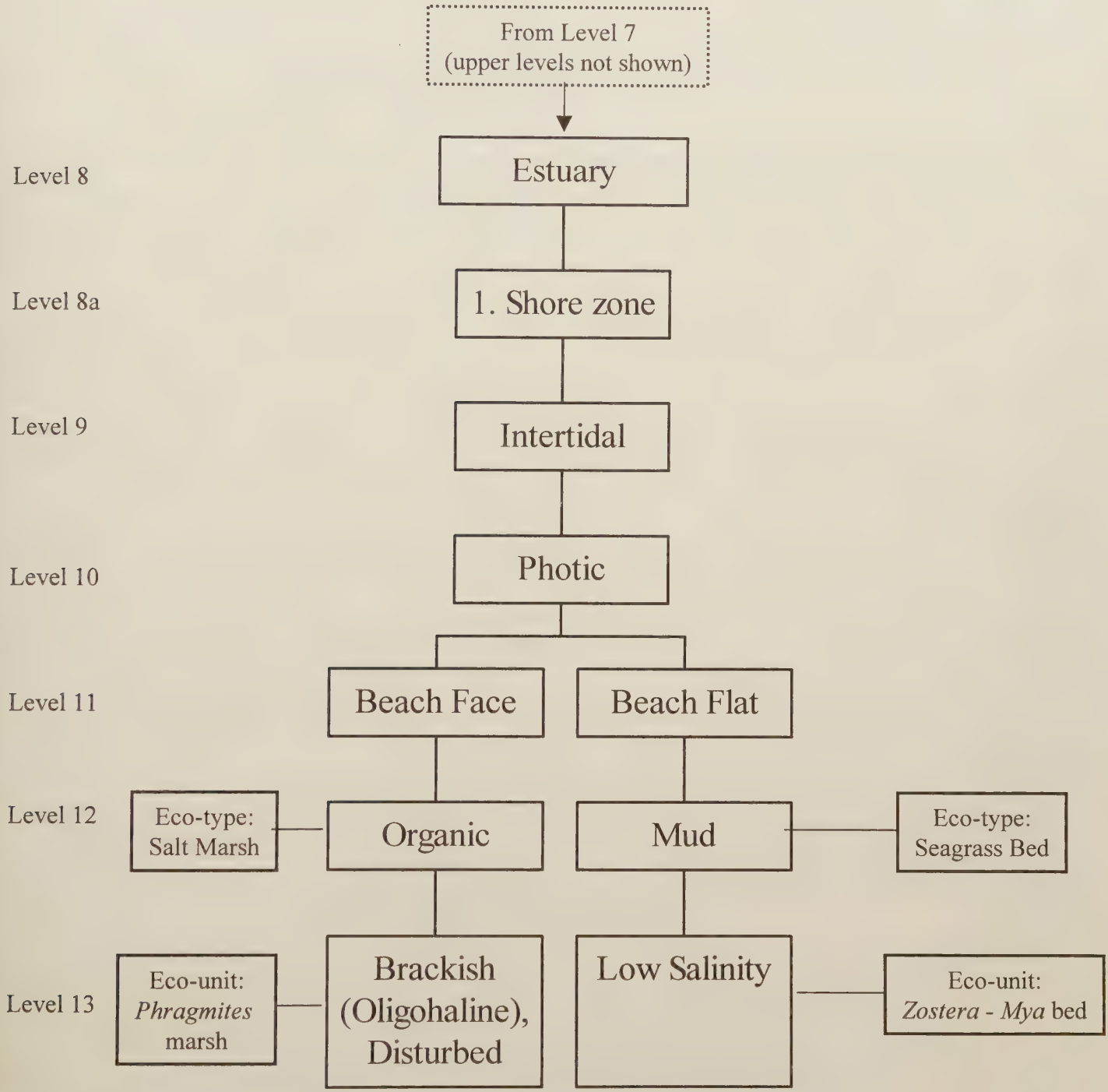


Figure 4. Levels 5 through 13 of the proposed marine and estuarine habitat classification system for continental water column. Note that for water column habitats, Level 11, "Geomorphic Types or Topography and Level 12, "Substratum", are not applicable.

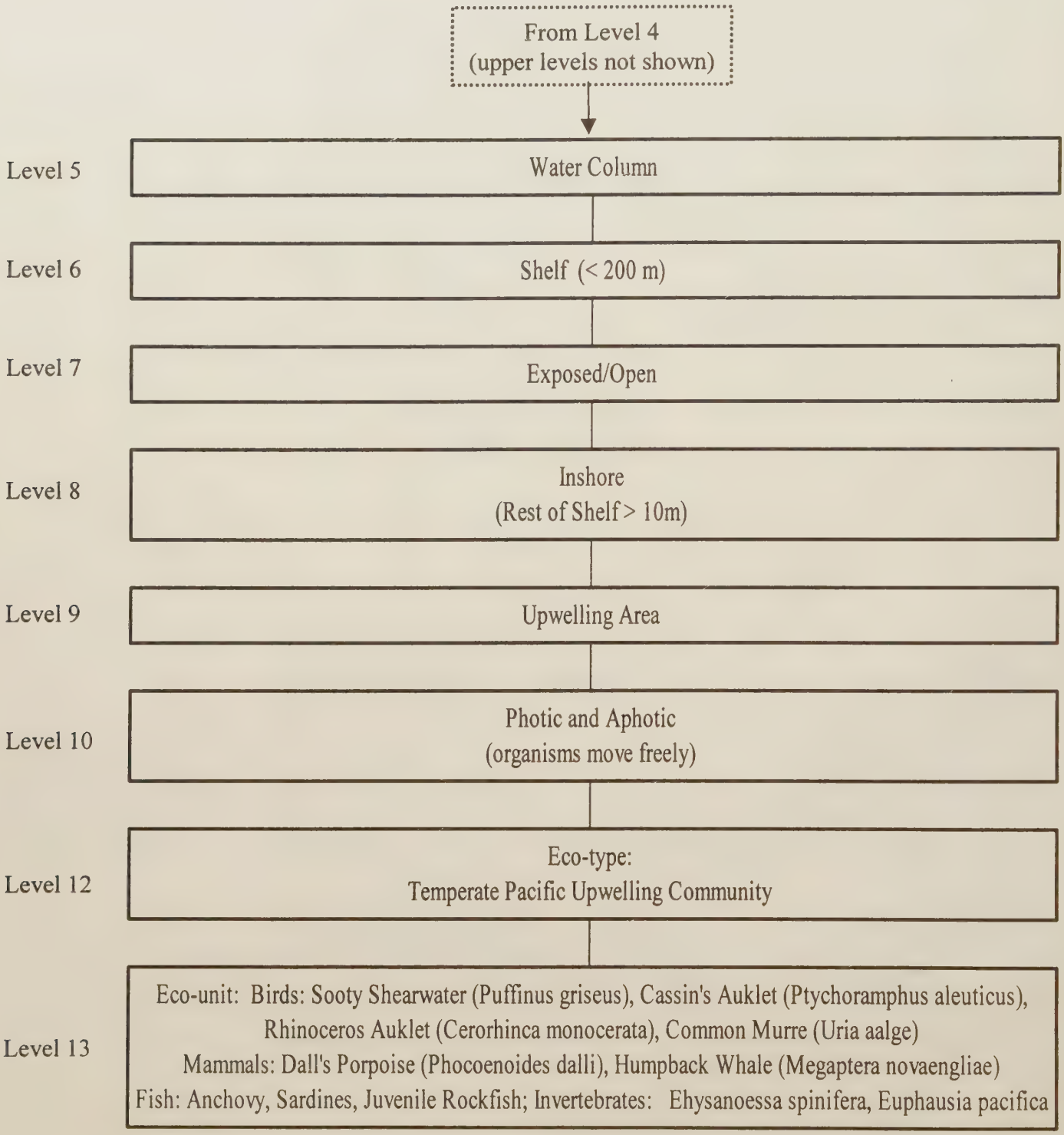


Figure 5. Levels 8 through 13 of the proposed marine and estuarine habitat classification system for continental shoreline habitat.

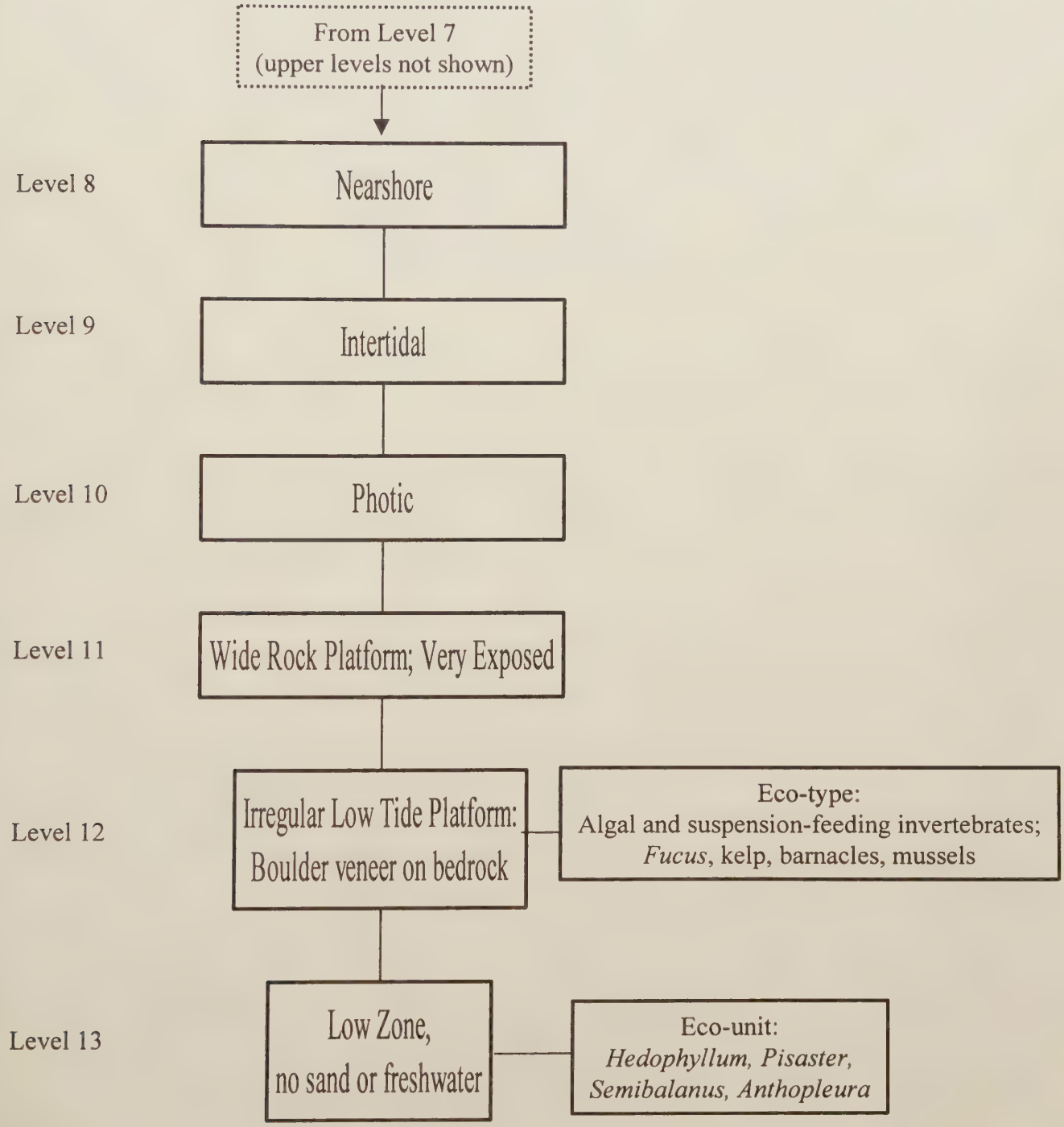


Figure 6. Levels 8 through 13 of the proposed marine and estuarine habitat classification system for a mangrove ecosystem.

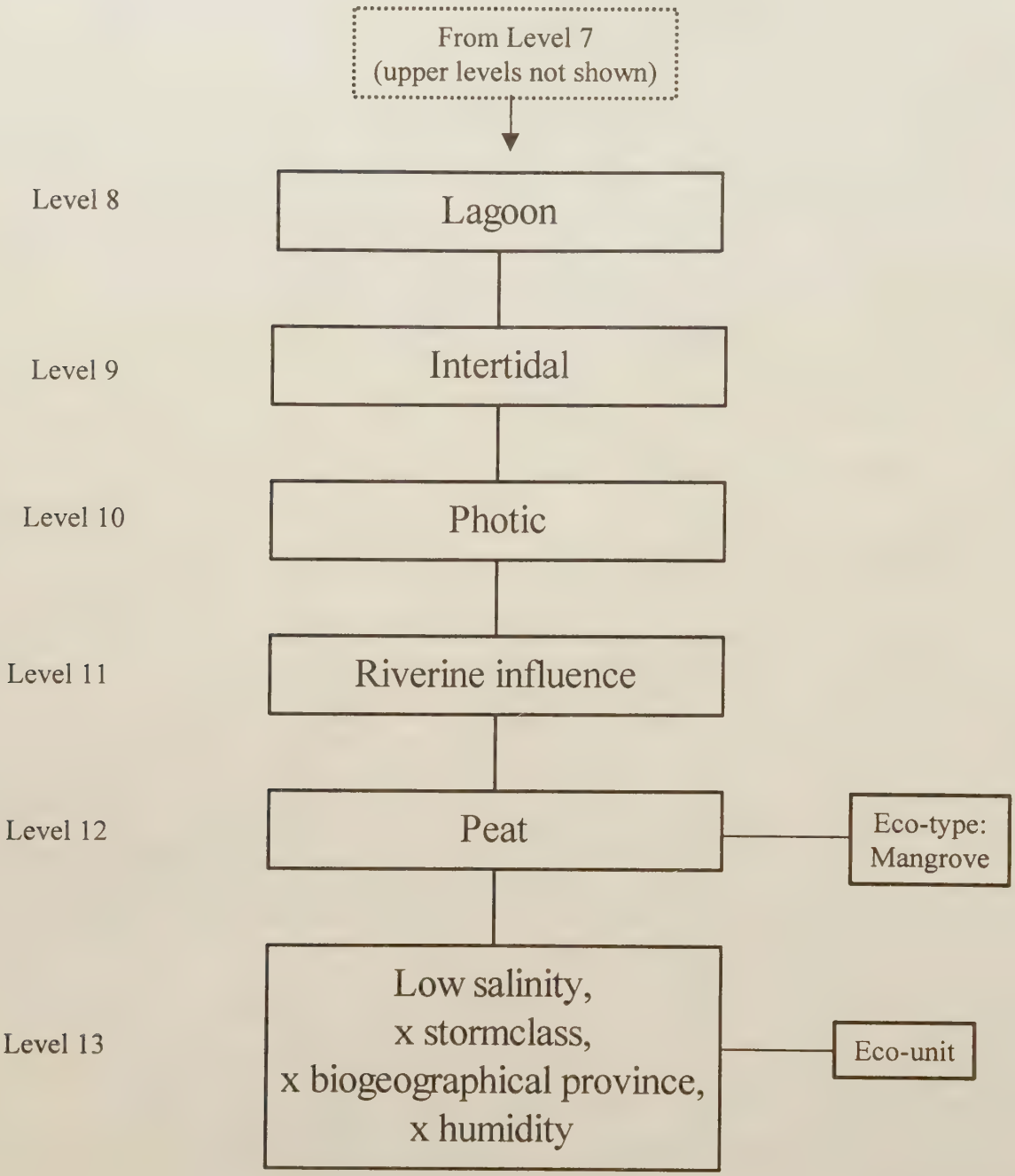


Figure 7. Levels 8 through 13 of the proposed marine and estuarine habitat classification system for benthic continental outer shelf and upper slope.

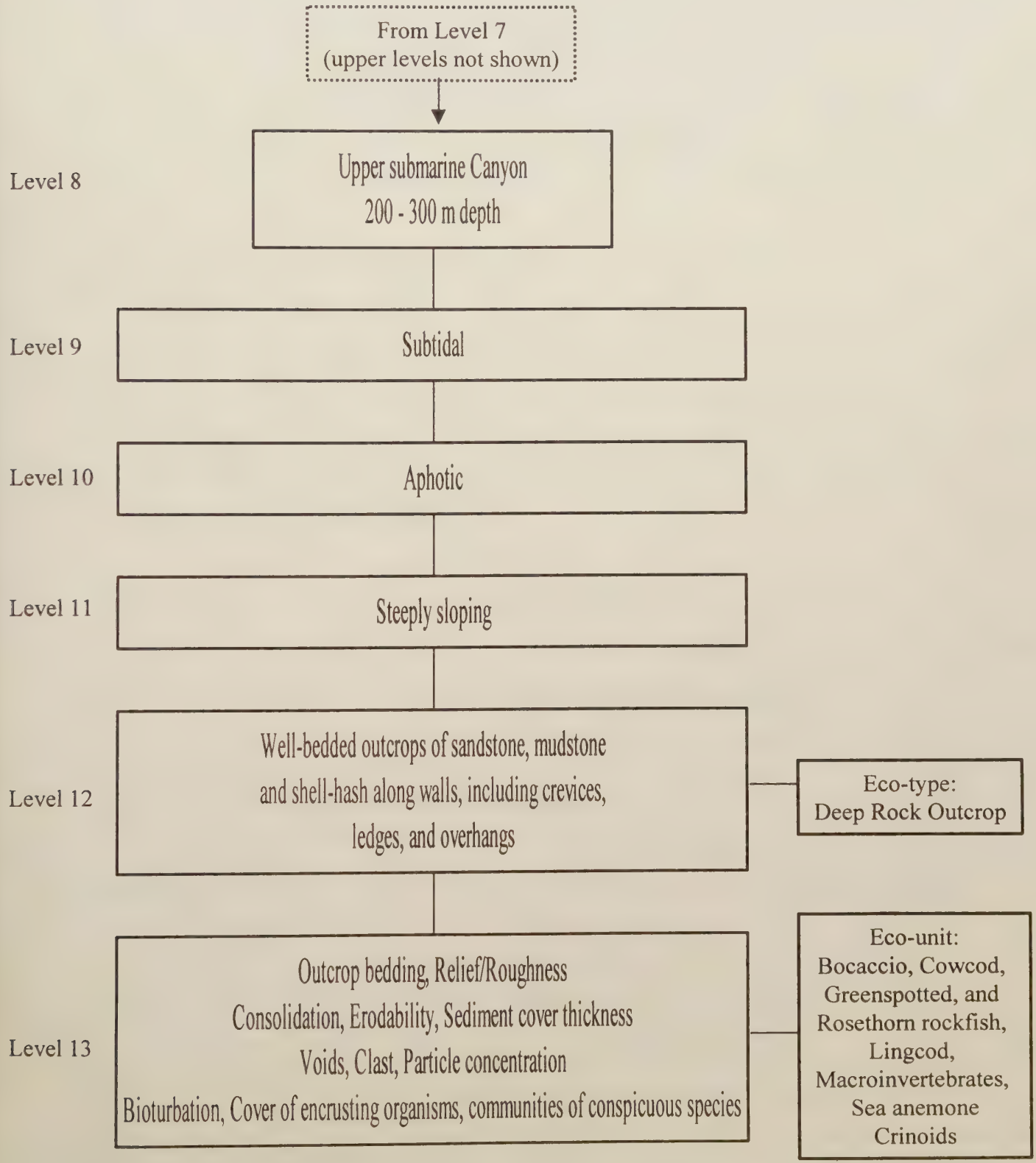


Figure 8. Levels 8 through 13 of the proposed marine and estuarine habitat classification system for Pacific Reefs (mostly based on key marine plants & stony corals).

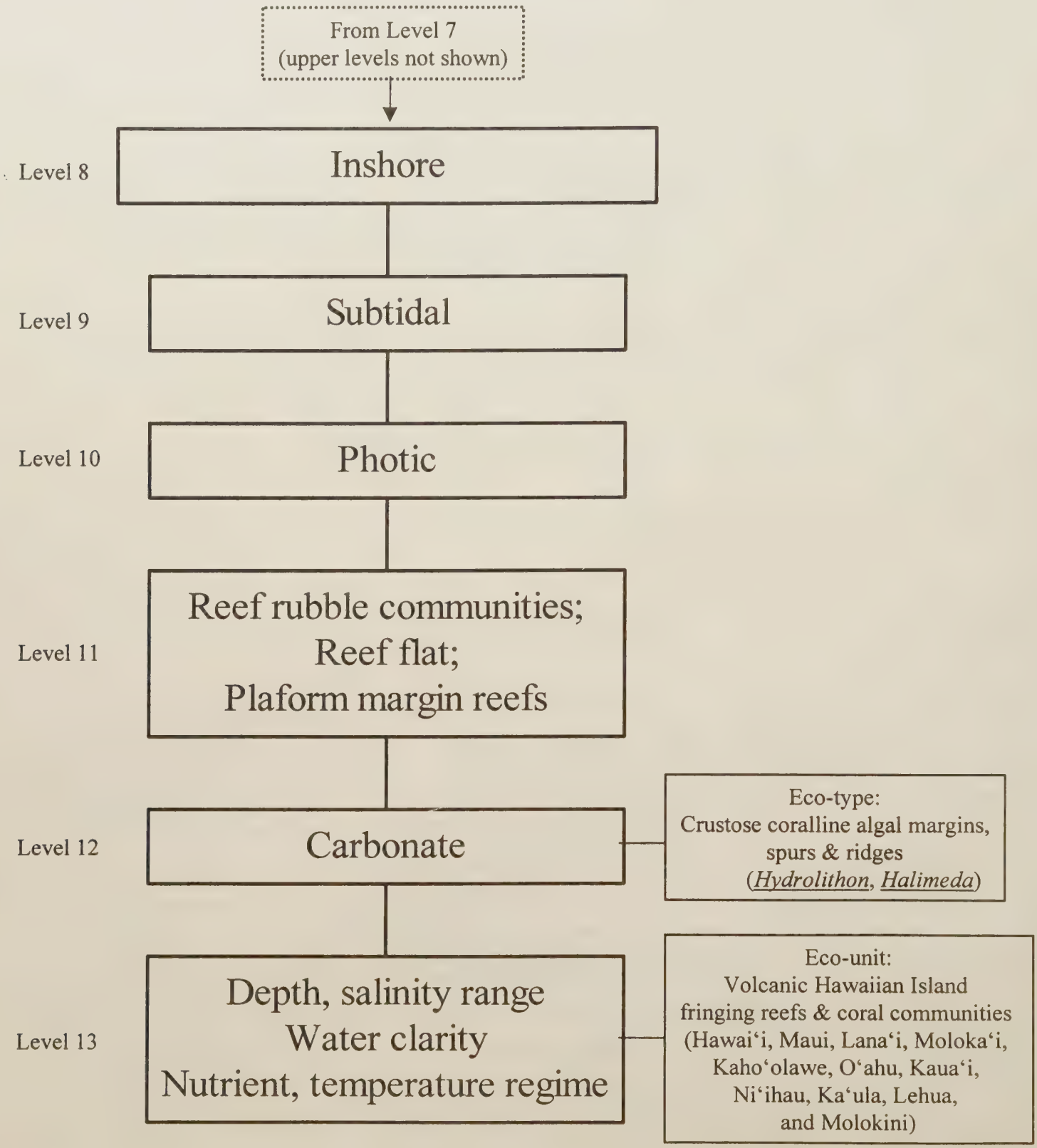
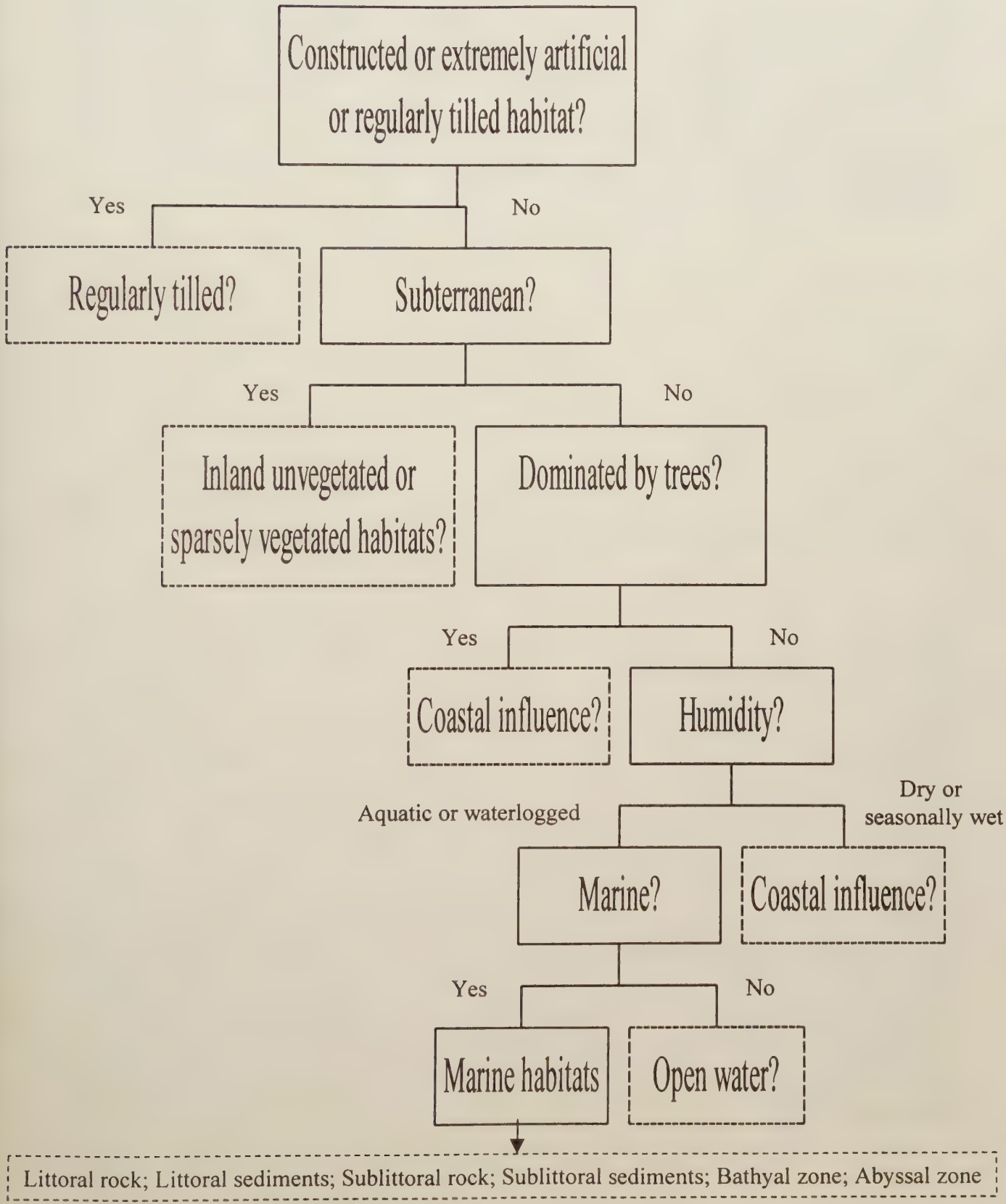


Figure 9. Upper levels of decision tree for the EUNIS Habitat Classification.



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